DOCUMENT RESUME

ED 429 584 IR 019 545

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TITLE WEBGUIDE: Guiding Collaborative Learning on the Web with Perspectives.

PUB DATE 1999-04-00

NOTE 21p.; Paper presented at the Annual Meeting of the American Educational Research Association (Montreal, Quebec, Canada, April 19-23, 1999). Colored photographs may not reproduce clearly.

PUB TYPE Reports - Descriptive (141) -- Speeches/Meeting Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS *Computer Assisted Instruction; *Computer Mediated Communication; *Computer Software Development; Computer System Design; *Cooperative Learning; Design Preferences; Educational Technology; Higher Education; Innovation; Middle Schools; World Wide Web

ABSTRACT

In January 1999, an interdisciplinary seminar of doctoral students from cognitive, educational and computational sciences was organized to study theoretical texts that might provide insight into how to support collaborative learning with perspectives-based software. The seminar uses a Web-based tool called WEBGUIDE to mediate and structure collaborative learning, including reflection on use of the software. This software uses an innovation mechanism to define a flexible system of perspectives on a shared knowledge construction space. WEBGUIDE provides an electronic and persistent workspace for individuals and teams to develop and share distinctive points of view on a topic. The software and associated usage practices are being designed by testing it in a middle school classroom and in an advanced graduate seminar. The experience in these usage situations has raised a range of questions concerning theoretical and practical issues, which are driving the research. This paper is a reflection on what the designers are learning collaboratively about how software artifacts can mediate learning and shared cognition. Contains 36 references. (AEF)

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Paper presented at **AERA '99**: American Educational Research Association, 1999 Annual Meeting, Montreal, April 19-23, **Division C** (Learning and Instruction), **Section 4** (Learning Environments)

ED 429 584

WEBGUIDE: Guiding Collaborative Learning on the Web with Perspectives

Gerry Stahl and the WEBGUIDE Seminar*

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ABSTRACT

We are developing a Web-based tool called WEBGUIDE to mediate and structure collaborative learning. This software uses an innovative mechanism to define a flexible system of *perspectives* on a shared knowledge construction space. WEBGUIDE provides an electronic and persistent workspace for individuals and teams to develop and share distinctive points of view on a topic. We are designing the software and associated usage practices by trying it out in a middle school classroom and an advanced graduate seminar. Our experience in these use situations has raised a range of questions concerning theoretical and practical issues, which are driving our research. This paper is a reflection on what we are learning collaboratively about how software artifacts can mediate learning and shared cognition.

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* Participants in the Readings and Research in Cognitive Science seminar, Spring 1999, on "Computer Mediation of Collaborative Learning" are: Kirstin Butcher, John Caron, Gabe Johnson, Elizabeth Lenell, Scott Long, Rogerio dePaula, Paul Prestopnik, Tammy Sumner.

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INTRODUCTORY NARRATIVE

For some years now I have been interested in how to personalize the delivery of information from knowledge repositories to people based on their preferred *perspectives* on the information (Stahl, 1995; 1996). For instance, designers often critique an evolving design artifact from alternative technical points of view; different designers have different personal concerns and styles, requiring considerations based upon access to different rules of thumb, rationale, constraints, standards and other forms of domain knowledge. Computer design environments should support these important interpretive perspectives (Stahl, 1993a; 1993b). I am now primarily interested in applying similar mechanisms of perspectival computer support within contexts of collaborative learning (Stahl, 1999).

Last year, Ted Habermann – an information architect at NOAA who makes geophysical data available to school children over the Web – suggested to me that we try to develop some computer support for a project at his son's middle school. Dan Kowal, the environmental sciences teacher at the Logan School for Creative Learning in Denver, was planning a year-long investigation of alternative perspectives on the issue of "acid mine drainage" (AMD) – the pollution of drinking water supplies by heavy metals washed out of old gold mines. The fact that Dan and I were interested in "perspectives" from different perspectives seemed to provide a basis for fruitful collaboration. Ted obtained NSF funding for the project and we all spent last summer planning the course and its perspectives-based software. Each of us brought in colleagues and worked to create a Java application (WEBGUIDE), a set of auxiliary web pages, a group of adult mentors representing different perspectives on AMD and a course curriculum.

The class started in September and the software was deployed in October. The students in Dan's class were aware of the experimental nature of the software they were using and were encouraged to critique it and enter their ideas into WEBGUIDE. Feedback from these twelve-year-old students provided initial experience with the usability of WEBGUIDE and resulted in a re-implementation of the interface and optimization of the algorithms over Christmas vacation.

In January, I organized an interdisciplinary seminar of doctoral students from cognitive, educational and computational sciences to study theoretical texts that might provide insight into how to support collaborative learning with perspectives-based software. The seminar uses WEBGUIDE as a major medium for communication and reflection, including reflection on our use of the software. This provides a second source of experience and raises a number of issues that will need to be addressed in software redesign this summer.

In this paper I would like to begin a reflection on the issues that have arisen through our WEBGUIDE experiences because I think they are critical to the ability to support collaborative learning with computer-based environments. The potential for computer mediation of collaboration seems extraordinary, but our experience warns us that the practical barriers are also enormous. Certainly, our experiences are not unique, and similar projects at the universities of Toronto, Michigan, Berkeley, Northwestern, Vanderbilt, Georgia Tech, etc. have run into them for years. Indeed, we observed many of these issues in a seminar last year prior to the implementation of WEBGUIDE (dePaula, 1998; Koschmann & Stahl, 1998). However, I believe that perspectives-based software addresses or transforms some of the issues and raises some of its own.

Now let me describe our experience in the two situations of classroom practice and explain the underlying computational perspectives approach.

PRACTICE I: ENVIRONMENTAL PERSPECTIVES

An early implementation of WEBGUIDE is in use in Dan's classroom at the Logan School. For the past five years, his class of middle school students has researched the environmental damage done to mountain streams by "acid mine drainage" from deserted gold mines high in the Rocky Mountains above Denver. The students actually solved the technical problem at the source of a stream coming into Boulder from the Gamble Gulch mine site by building an artificial constructed wetlands area to filter out heavy metals. This year they are investigating the broader ramifications of their success; they are looking at the social issue of acid mine drainage from various alternative – and presumably conflicting – perspectives. The students interview adult mentors to get opinions from specific perspectives: environmental, governmental, mine-owner and local landowner. Then, working in teams corresponding to each of these perspectives, they articulate the position of their perspective on a set of shared questions.

The "Gamble Gulch" application of WEBGUIDE serves as the medium through which the students collaboratively research these issues with their mentors and with teammates. Each student and mentor has their personal display perspective, and their display perspectives each inherit from one of the content-based team perspectives (environmental protection, governmental regulation, etc.), depending upon which intellectual perspective they are working on constructing.

Figure 1 shows one student's (Blake) personal perspective on the class discourse. The tree of discussion threads was "seeded" with question categories, such as "Environmental Analysis Questions". Within these categories, the teacher posted specific questions for the students to explore, like, "Do you believe that AMD is a serious threat to the environment?" Here, Blake has sent an email to a mentor asking for information related to this question. Email interactions happen through WEBGUIDE and are retained as notes in its display perspectives. When replies are sent back, they are automatically posted to the discussion outline under the original email. When someone clicks on a title, the contents of that note are displayed in an HTML frame below the applet (as is the body of the student's email in Figure 1).

Blake is working in his personal perspective, which inherits from the class, student team and landowner team perspectives (see the red arrows in Figure 2). Note that the display of his personal perspective (in Figure 1) includes notes that Dan and I entered in the student perspective to structure the work of all the students. Blake can add, edit and delete ideas in his perspective, as well as sending email in it. Because he is a member of the landowner team and the student group as well as the class, he can browse ideas in the Student comparison, the Landowner comparison and the Gamble Gulch class comparison perspectives (see list of perspectives accessible to him on the right of Figure 1).

For this application, the teacher has decided that perspective comparing and negotiation will take place in live classroom discussions, rather than in WEBGUIDE. After a team or the whole class reaches a consensus, the teacher will enter the statements that they have agreed to into the team or class perspective.

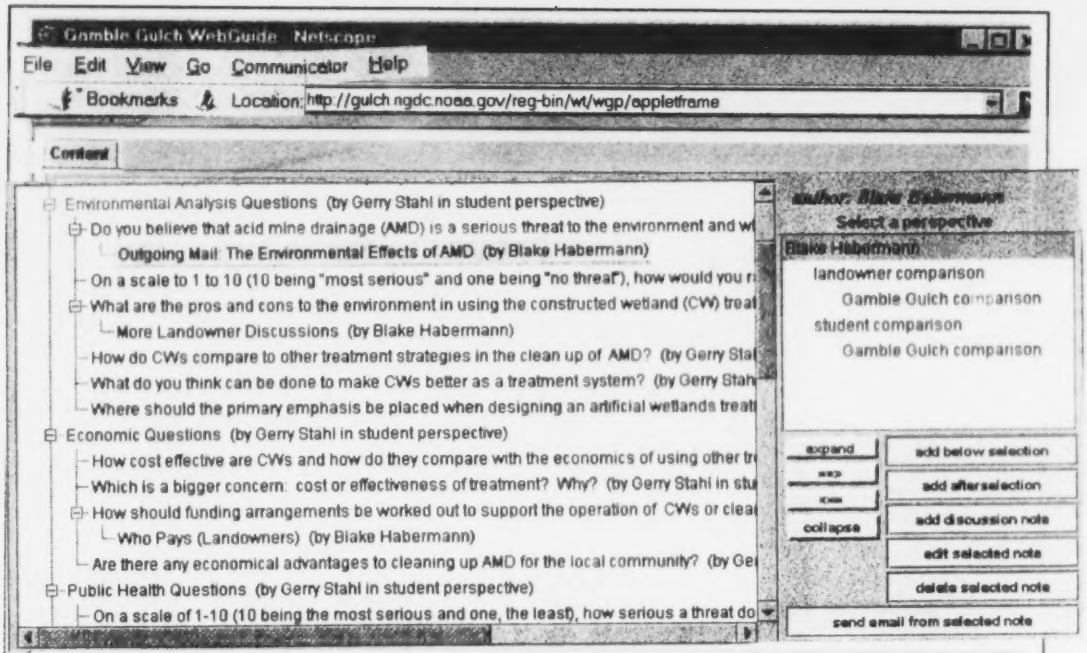
Gamble Gulch WebGuide - Netscape
File Edit View Go Communicator Help
Bookmarks Location: http://gulch.ngdc.noaa.gov/reg-bin/wt/wgp/appletframe
Content
Environmental Analysis Questions (by Gerry Stahl in student perspective)
Do you believe that acid mine drainage (AMD) is a serious threat to the environment and wi
Outgoing Mail: The Environmental Effects of AMD (by Blake Habermann)
On a scale to 1 to 10 (10 being "most serious" and one being "no threat"), how would you ra
What are the pros and cons to the environment in using the constructed wetland (CW) treat
More Landowner Discussions (by Blake Habermann)
How do CWs compare to other treatment strategies in the clean up of AMD? (by Gerry Stal
What do you think can be done to make CWs better as a treatment system? (by Gerry Stahl
Where should the primary emphasis be placed when designing an artificial wetlands treat
Economic Questions (by Gerry Stahl in student perspective)
How cost effective are CWs and how do they compare with the economics of using other tr
Which is a bigger concern: cost or effectiveness of treatment? Why? (by Gerry Stahl in stu
How should funding arrangements be worked out to support the operation of CWs or clea
Who Pays (Landowners) (by Blake Habermann)
Are there any economical advantages to cleaning up AMD for the local community? (by Ge
Public Health Questions (by Gerry Stahl in student perspective)
On a scale of 1-10 (10 being the most serious and one, the least), how serious a threat do
Select a perspective
Blake Habermann
landowner comparison
Gamble Gulch comparison
student comparison
Gamble Gulch comparison
expand
collapse
add below selection
add after selection
add discussion note
edit selected note
delete selected note
send email from selected note
Outgoing Mail: The Environmental Effects of AMD
Dear Mr. Bartlo,
Another e-mail from the Logan school for you. Please respond to these three questions:
1. On a scale of 1-10 (10 being serious, 1 being no threat), how would you rate AMD as an environmental threat?
2. What do you think are the pros and cons of using Constructed Wetlands in AMD cleanup?
3. How do you think CW's compare to the other ways of treating AMD?
Please note that we will be on break until the first of the year, so any returns won't be responded to until that time.
Document Done

Figure 1. The Gamble Gulch version of WEBGUIDE viewed in a Web browser. The top part is a Java applet displaying an outline view of note titles. The content of the selected note is displayed in an HTML frame below. To the right are buttons for navigating the outline and changing the content in the shared knowledge space. The view shown is from the personal perspective of one student.

The goal of the year-long course is not only to negotiate within teams to construct the various positions, but also to negotiate among the positions to reach consensus or to clarify differences. Dan designed this class – with its use of WEBGUIDE – to teach students that knowledge is perspectival, that different people construct views, compilations of facts and arguments differently depending upon their social situation. He hopes that his students will not only learn to evaluate statements as deriving from different perspectives, but also learn to negotiate the intertwining of perspectives to the extent that this is possible.

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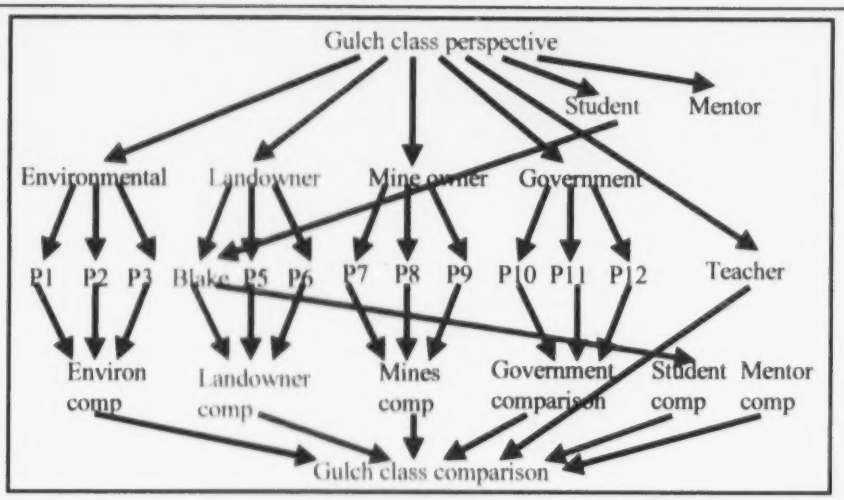
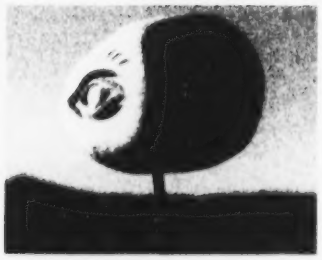


Figure 2. The web of perspectives in Gamble Gulch. Information is automatically inherited downward in the diagram. Blake's perspective includes all the notes entered in the Gulch class, Landowner and Student perspectives. His notes also show up in the Landowner, Student and Gulch class comparison perspectives.

DEFINITION OF PERSPECTIVES



The term "perspectives" is over-loaded with meanings; this frequently produces confusion even when it is intended to tacitly exploit aspects of the perspectives metaphor from one domain into another. It may be helpful at this point to distinguish three types of perspectives: literal, figurative and computational.

- *Literal perspectives* are optical or perceptual orientations: one sees objects from the specific angle or vantage point of the physical location of ones eyes.
- *Figurative perspectives* take metaphorical license and refer to, for instance, different ways of conceptualizing a theme, as in adopting a skeptical view of a conversational claim.
- *Computational perspectives* are the result of software mechanisms that classify elements in a database for selective display. In WEBGUIDE, for example, if I enter a note in my personal perspective then that note will be displayed whenever my perspective is displayed but not when someone else's personal perspective is displayed.

WEBGUIDE implements a system of computational perspectives designed to exploit the perspective metaphor in order to support characteristics of collaboration and collaborative learning. It is unique in a number of ways that distinguish it from other software systems that may use the term "perspectives":

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- Other systems refer to different *representations* of information as perspectives. They might have a graphical and a textual view of the *same* data. In WEBGUIDE, different data is displayed in different perspectives – using the same representation, hierarchically structured titles of textual notes.
- In WEBGUIDE, the perspectives mechanism is neither a simple tagging of data nor a database view, but is a dynamic computation that takes into account a *web of inheritance* among perspectives. Thus, Blake's perspective includes not only information that he entered in his perspective, but also information inherited from the Class, Student and Landowner perspectives.
- Furthermore, the web of perspectives can be extended by users *interactively* and the inheritance of information is always computed based on the current configuration of this web.
- In addition, the information in a perspective has a user-maintained structure in which each note has one or more parent notes and may have children notes, creating a *web of notes* within each perspective. The order of children displayed under a parent note is user-defined and maintained so that WEBGUIDE can be used to *organize ideas* within outline structures.

The idea of perspectives on the Web traces its lineage to ideas like "trail blazing" (Bush, 1945), "transclusion" (Nelson, 1981), and "virtual copies" (Mittal et al., 1986) – techniques for defining and sharing alternative views on large hypertext spaces. At the University of Colorado we have been exploring this approach to computational perspectives in desktop applications for the past decade (McCall et al., 1990; Stahl, 1993b). WEBGUIDE is our first truly Web-based version. The core of WEBGUIDE consists of a perspectives server named POW! (Perspectives On the Web), which communicates with Java, Perl or HTML interfaces.

The computational perspectives mechanism we have been exploring incorporates the following features for a community of users (Stahl, 1993a):

- Individual community members have access to what appears to be their own information source. This is called their *personal perspective*. It consists of notes from a shared central information repository that are tagged for display within that particular perspective (or in any perspective inherited by that perspective).
- Notes can be created, edited, rearranged, linked together or deleted by users within their own personal perspective without affecting the work of others.
- Another student, Annie, can integrate a note from Blake's perspective into her own personal perspective by creating a *link* or virtual copy of the note. If Blake modifies the original note, then it changes in Annie's perspective as well. However, if Annie modifies the note, a new note is actually created for her, so that Blake's perspective is not changed. This arrangement generally makes sense because Annie wants to view (or inherit) Blake's note, even if it evolves. However, Blake should not be affected by the actions of someone who copied one of his notes.
- Alternatively, Annie can *physically copy* the contents of a note from Blake's perspective. In this case, the copies are not linked to each other in any way. Since Annie and Blake are viewing physically distinct notes now, either can make changes without affecting the other's perspective.
- There is an inheritance web of perspectives; descendants inherit the contents of their ancestor perspectives. Changes (additions, edits, deletions) in the ancestor are seen in descendent perspectives, but not vice versa. New perspectives can be created by users. Perspectives can inherit from existing

perspectives. Thus, a team perspective can be created that includes virtual copies of all contents of the inherited perspectives of the team members. A hierarchy of team, sub-team and individual perspectives can be built to match the needs of a particular community.

This model of computational perspectives has the important advantage of letting team members inherit the content of their team's perspective and other information sources without having to generate it from scratch. They can then experiment with this content on their own without worrying about affecting what others see. This is advantageous as long as one only wants to use someone else's information to develop one's own figurative perspective. Such "perspective-making" is important in thinking about and judging issues from particular perspectives.

However, if one wants to influence the content of other team members' perspectives through "perspective-taking" (Boland & Tenkasi, 1995), then this approach is limited because one cannot change someone else's content directly. Moreover, for supporting collaborative work it is important that the perspectives maintain at least a partial overlap of their contents in order to reach successful mutual understanding and coordination. The underlying subjective opinions must be intertwined to establish intersubjective understanding (Tomasello et al., 1993). We are interested in exploring how to support the intertwining of perspectives with our computational perspectives mechanisms. We will return to this issue after describing the types of perspectives used in our applications.

TYPES OF PERSPECTIVES

WEBGUIDE provides several levels of perspectives within a web of perspective inheritance to help students compile their individual and joint research:

- The *class perspective* is created by the teacher to start each team off with an initial structure and some suggested topics. It typically establishes a framework for classroom activities and defines a space used to instantiate the goal of collecting the products of collaborative intellectual work.
- The *team perspective* contains notes that have been accepted by a team. This perspective can be pivotal; it gradually collects the products of the team effort.
- The student's *personal perspective* is a private work space. It inherits a view of everything in the student's team's perspective. Thus, it displays the owner's own work within the context of notes proposed or negotiated by the team and class – as modified by the student. Students can each modify (add, edit, delete, rearrange, link) their virtual copies of team notes in their personal perspectives. They can also create completely new material there. This computational perspective provides a personal workspace in which a student can construct his or her own figurative perspective on shared knowledge.
- The *comparison perspective* combines all the personal perspectives of team members and the team perspective, so that anyone can compare all the work that is going on in the team. It inherits from the personal, team and class perspectives. Students can go here to get ideas and copy notes into their own personal perspective or propose items for the team perspective.

Of course, there is not really a duplication of information in the community memory. The perspectives mechanism merely displays the information differently in the different perspectival views, in accordance with the relations of inheritance.

To design software for collaborative learning in schools means to design curriculum and classroom process as well (Stahl et al., 1995a; 1995b). Computer support has to be matched with appropriate content (typically stored in WEBGUIDE or on the Web) and with constructivist practices for knowledge-building communities (Scardamalia & Bereiter, 1991). The design of the WEBGUIDE interface and the perspectives mechanism must be adapted to individual application situations, with appropriate seeding of content, structuring of the perspectives web and establishing of access policies.

In Logan School, for instance, students each enter notes in their personal perspectives using information available to them: from the Web, books, encyclopedia, discussions, interviews of mentors or other sources. Students can review the notes in the class perspective, their team perspective and the personal perspectives of their teammates. All of these contents are collected in comparison perspectives, where they are labeled by their perspective of origin. Students extract from the research those items that are of interest to them. Then they organize and develop the data they have collected by categorizing, summarizing, labeling and annotating. The stages of investigating, collecting and editing can be iterated as many times as desired. Team members then negotiate which notes should be promoted to the team perspective to represent their collaborative statement of their perspective on acid mine drainage.

ISSUES FOR PERSPECTIVES

As an initial field testing of the WEBGUIDE system, the Logan School trial is generating valuable experience in the practicalities of deploying such a sophisticated program to young students over the Web. The students are enthusiastic users of the system and offer (within WEBGUIDE) many ideas for improvements to the interface and the functionality. Consequently, WEBGUIDE is benefiting from rapid cycles of participatory design. The differing viewpoints, expectations and realities of the software developers, teachers and students provide a dynamic field of constraints and tensions within which the software, its goals and the understanding of the different participants co-evolve.

The first issues to hit home when we deployed WEBGUIDE were the problems of response time and screen real estate. The student computers were slower, had smaller monitors, lacked good Internet connections and were further from the server than the computers of the developers. We were, of course, already familiar with these issues from other Web applications, but one never knows quite how things will work out and how they will be accepted until one tests them under classroom conditions.

A pre-release prototype of WEBGUIDE used dynamic HTML pages. This meant that each time one expanded a different part of the outline of titles one had to wait for a new page to be sent across the Internet. It also greatly constrained the interface functionality. However, when we moved to a Java applet, we had to wait several minutes to download the applet code to each student computer. Furthermore, it entailed running all the perspectives computations on the slow student computer. In order to reduce the download time significantly, we first rewrote the interface using standard Java Swing classes that can be stored on the student machines. Then we split the applet into a client (the interface) and a server (the

perspectives computations and database access). By downloading only the client part to the classroom, we not only reduced the download time further, but also ran the time-consuming computations on our faster server computers.

Such technical problems can be solved relatively easily, by optimizing algorithms or by adjusting trade-offs based on local conditions. Issues of social practice are much more intransigent. There seem to be two major issues for software like WEBGUIDE, that is, software for threaded discussions and collaborative knowledge construction:

1. Lack of convergence among the ideas developed in the supported discussions.
2. Avoidance of system use in favor of email, face-to-face conversation or inaction.

WEBGUIDE introduces its computational perspectives mechanism as a structural feature to facilitate the articulation of convergent ideas and even incorporates email. In attempting to address the above problems, it raises a new set of issues:

3. Is the perspectives metaphor a natural one (or can it be made natural) so that people will use computational perspectives to construct their figurative perspectives?
4. Can the web of perspectives be represented in a convenient and understandable format?

In our trials of WEBGUIDE we have tried to create learning situations that would encourage the use of the software, yet we have observed low levels of usage and under-utilization of the system's full functionality. This raises the following additional issues:

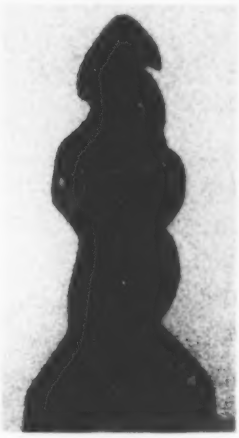
5. How can learning situations be structured to take better advantage of the presumed advantages of the software?
6. How can the system's various capabilities be distinguished, such as its support for threaded discussions and for perspective-making?

In order to answer questions of this magnitude it was necessary to gather more experience, to be more closely involved in the daily usage of the system and to develop a deeper theoretical understanding of collaborative learning and of computer mediation. Having defined these goals, I announced a seminar on the topic of "computer mediation of collaborative learning," open to interested researchers from a number of disciplines – primarily education, cognitive psychology and computer science. The goal of the seminar was explicitly stated to be an experiment in the use of WEBGUIDE to construct knowledge collaboratively, based on careful reading of selected texts. The texts traced the notion of *computer mediation* (Boland & Tenkasi, 1995; Caron, 1998; Hewitt et al., 1998; Scardamalia & Bereiter, 1996; Stahl, 1999) back to *situated learning theory* (Bruner, 1990; Cole, 1996; Lave, 1991; 1996; Lave & Wenger, 1991) – and from there back to the notion of *mediated consciousness* in Vygotsky (1930/1978) and its roots in Hegel (Habermas, 1971; Hegel, 1807/1967; Koyeve, 1947/1969) and Marx (1844/1967; 1845/1967; 1867/1976).

In the final section of this paper I will comment on our current understanding of the six issues listed above. But first it is necessary to describe the ways in which the seminar attempts to make use of WEBGUIDE and the conceptualization of the theory of computer mediation that is arising in the seminar.

PRACTICE II: THEORETICAL PERSPECTIVES

The seminar on computer mediation of collaborative learning is designed to use WEBGUIDE in several ways:



- *As the primary communication medium for internal collaboration.* The seminar takes place largely on-line. Limited class time is used for people to get to know each other, to motivate the readings, to introduce themes that will be followed up on-line, and to discuss how to use WEBGUIDE within the seminar.
- *As an example collaboration support system to analyze.* Highly theoretical readings on mediation and collaboration are made more concrete by discussing them in terms of what they mean in a system like WEBGUIDE. The advantage of using a locally-developed prototype like WEBGUIDE as our example is that we not only know how it works in detail, but we can modify its functionality or appearance to try out suggestions that arise in the seminar.
- *As an electronic workspace for members to construct their individual and shared ideas.* Ideas entered into WEBGUIDE persist there, where they can be revisited and annotated at any time. Ideas that arise early in the seminar will still be available in full detail later so that they can be related to new readings and insights. The record of discussions over a semester or a year will document how perspectives developed and interacted.
- *As a glossary and reference library.* This application of WEBGUIDE is seeded with a list of terms that are likely to prove important to the seminar and with the titles of seminar readings. Seminar members can develop their own definitions of these terms, modifying them based on successive readings in which the terms recur in different contexts and based on definitions offered by other members. Similarly, the different readings are discussed extensively within WEBGUIDE. This includes people giving their summaries of important points and asking for help interpreting obscure passages. People can comment on each other's entries and also revise their own. Of course, new terms and references can be added easily by anyone.
- *As a brainstorming arena for papers.* The application has already been seeded with themes that might make interesting research papers drawing on seminar readings and goals. WEBGUIDE allows people to link notes from anywhere in the information environment to these themes and to organize notes under the themes. Thus, both individuals and groups can use this to compile, structure and refine ideas that may grow into publishable papers. Collaborative writing is a notoriously difficult process which generally ends up being dominated by one participant's perspective or being divided up into loosely connected sections, each representing a single perspective. WEBGUIDE may facilitate a more truly collaborative approach to organizing ideas on a coherent theme.
- *As a bug report mechanism or feature request facility.* Seminar participants can communicate problems they find in the software as well as propose ideas they have for new features. By having these reports and proposals shared within the WEBGUIDE medium, they are communicated to other seminar participants, who can then be aware of the bugs (and their fixes) and can join the discussion of suggestions.

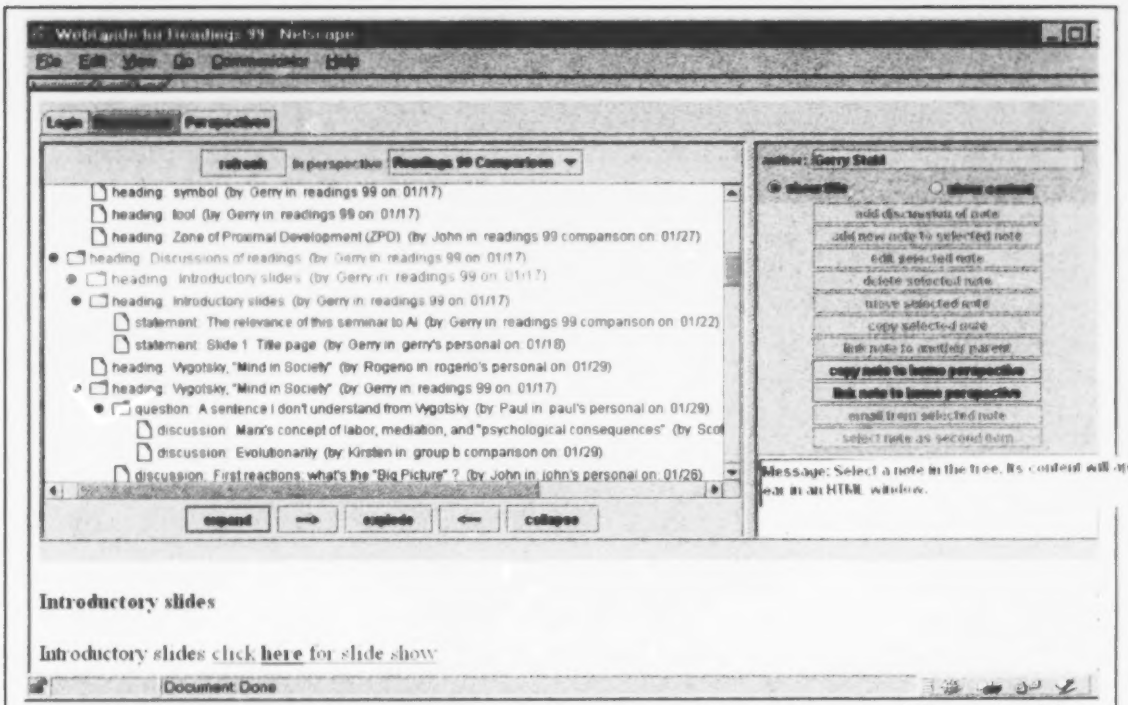

File Edit View Go Communicator Help
Login
Perspectives
refresh
heading symbol (by Gerry in readings 99 on 01/17)
heading tool (by Gerry in readings 99 on 01/17)
heading Zone of Proximal Development (ZPD) (by John in readings 99 comparison on 01/27)
heading Discussions of readings (by Gerry in readings 99 on 01/17)
heading Introductory slides (by Gerry in readings 99 on 01/17)
heading Introductory slides (by Gerry in readings 99 on 01/17)
statement The relevance of this seminar to AI (by Gerry in readings 99 comparison on 01/22)
statement Slide 1 Title page (by Gerry in gerry's personal on 01/18)
heading Vygotsky, "Mind in Society" (by Rogerio in rogerio's personal on 01/29)
heading Vygotsky, "Mind in Society" (by Gerry in readings 99 on 01/17)
question A sentence I don't understand from Vygotsky (by Paul in paul's personal on 01/29)
discussion Marx's concept of labor, mediation, and "psychological consequences" (by Scot
discussion Evolutionarily (by Kirsten in group b comparison on 01/29)
discussion First reactions: what's the "Big Picture" ? (by John in john's personal on 01/26)
expand
explode
collapse
copy selected note
copy note to home perspective
Introductory slides
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Figure 3. The version of WEBGUIDE used in the seminar. Note that some of the control buttons on the right are not functional when the logged-in author is not working in his own personal perspective. This enforces certain social practices. Also note that many headings have been inserted to structure the discussion space.

The seminar version of WEBGUIDE incorporates a built-in permissions system that structures the social practices surrounding the use of the system. Seminar participants each have their own personal perspective in which they can manipulate notes however they like without affecting the views in other perspectives. They can add quick discussion notes or other kinds of statements. They can edit or delete anything within their personal perspective. They can also make multiple copies or links (virtual copies) from notes in their personal perspective to other notes there. Anyone is free to browse in any perspective. However, if one is not in ones own perspective then one cannot add, edit or delete notes there (as in Figure 3). To manipulate notes freely, one must first copy or link the note into ones own personal perspective. The copy or link can optionally include copying (or virtual copying) all the notes below the selected note in the tree as well. These rules are enforced by the user interface, which checks whether or not someone is in their personal perspective and only allows the legal actions.

Students in the class can form sub-groups either within or across their different disciplines. They develop ideas in their personal perspectives. They debate the ideas of other people by finding notes of interest in the class comparison perspective (or in a subgroup comparison perspective) and copying these notes into their own personal perspective, where they can comment on them. The clash of perspectives is visible in the comparison perspectives, while the personal perspectives allow for complete expression and organization of a single perspective. This supports the taking of other people's perspectives and the use of shared ideas in the making of ones own perspectives (Boland & Tenkasi, 1995).

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The seminar application of WEBGUIDE stresses the use of perspectives for structuring collaborative efforts to build shared knowledge. The goal of the seminar is to evolve theoretical views on computer mediation – and to do so within a medium that supports the sharing of tentative positions and documents the development of ideas and collaboration over time. A major hypothesis investigated by the seminar is that software environments with perspectives – like WEBGUIDE – can provide powerful tools for coordinated intellectual work and collaborative learning. It explores how the use of a shared persistent knowledge construction space can support more complex discussions than ephemeral face-to-face conversation. Many of the desires and concerns in this paper arose in notes in WEBGUIDE as part of the seminar. In particular, the seminar's focus on theory as our practice has problematized our understanding of the role of theory.

THEORY IN PRACTICE

Our initial application of WEBGUIDE in the middle school environmental course raised a number of issues that led us to seek theoretical understanding through a seminar, which is serving as a second application of WEBGUIDE. We have begun to see our research differently as a result of the theories we are incorporating in our reflections within the seminar. One thing that has changed is the relation we see of this theory to our research practice.

In my paper proposal to AERA, written prior to our recent explorations, I described our approach by following the narrative order implied by conventional wisdom about the relation of theory to practice. After stating the goal or purpose of the work, I provided a theoretical framework, followed by sections on techniques, evidence, conclusions and educational / scientific import. The assumption here was that when one had a problem one turned first to theory for the solution and then "applied" the theory to some situation – either the problem situation or an experimental test context. After designing the solution based on the pre-existing theory and applying it to the test situation, one gathered evaluative data and analyzed the data to measure success. The evaluation then implies whether or not the solution has generalizable import.

But such an approach is in keeping neither with our current experience nor with our emerging theory. We started last summer with an opportunity to explore some vague notions we had about something we called "perspectives". We experimented with ever-evolving techniques through a complex collaborative process involving many people, each with their own concerns, understanding and insights. As part of this process some of us turned to theory – but the selection of theoretical texts and our interpretations of them were determined by the processes and issues we observed in our practical strivings.

So in this draft of the paper – still not considered a static final document, but a recapitulation from one particular moment in an on-going process – I am trying to narrate a different story about how theory and practice have been co-mingled in our research. We began with an idea for a concrete classroom curriculum and worked on designing tools and structures to support the practical needs of that curriculum. Once we had a working software prototype that could be used over the Web, we deployed it in the middle school classroom. We immediately confronted the realities of issues of response speed and monitor screen real estate that we had been worried about from the start. Students started asking for new functionality and it became clear that they were not using the implemented functions the way they were designed to be used. A dance commenced between the technicians, the educators, the students, the cur-

riculum and the software; as we circled each other, we changed and became more compatible with each other.

There was no point in trying to evaluate the success of our experiment by gathering data under controlled conditions. It was clear that we needed to figure out how to make things work better, not to measure precisely how well they were (or were not) already working. Beyond the relatively clear technical usability issues there were deeper questions of how software can mediate interpersonal and cognitive relations within collaboration (Hewitt et al., 1998). This led us to look for a theory of computer mediation – and for that matter a theory of collaborative learning – in the graduate seminar. Of course, it turned out that there are no adequate theories on these topics sitting on the bookshelf for us to simply apply. Rather, we had to undertake the construction of such theory, building upon hints strewn around in texts from many disciplines and guided by the problematic in which we are involved first hand.

Trusting in our intuition that software like WEBGUIDE could facilitate group theory building, we set out to use WEBGUIDE in our theoretical investigations, and thereby drive the further development of the software through additional practical experience even as we were developing theoretical justifications for our design. In reflecting on our experience, I have tried to organize this draft of the paper in accordance with a non-traditional theory about the relation of theory and practice – an understanding of this relationship more in keeping not only with our practice but with our hermeneutic, dialectical, socially situated activity theory.

Thus, we started out from our vague, only partially articulated background understanding of perspectives as an interesting and promising concept for learning and for computer support (Stahl, 1999). We set up a real-world situation in which we could explore what happens. In this situation we nurtured a process of "structural coupling" (Maturana & Varela, 1987) in which the different actors evolve toward a workable synthesis or homeostasis. Rapid prototyping cycles and participatory design sessions help facilitate this process. As breakdowns in how things were intended to work are recognized, we engage in reflection-in-action (Schön, 1983) to make our tacit pre-understanding explicit, to understand what has happened and to project corrective actions. This process of explication raises generalizable issues and calls for theory. But despite the generality of the issues, the theory is not understood in a completely abstract way, but in terms of its relevance to our situation and to the specific barriers we have uncovered in that concrete situation (Stahl, 1993a).

Theory – like everyday thought – often arises after the fact (or well into the complex process of practical investigations) in order to justify situations that would otherwise be too messy to comprehend and remember. Then, first chance it gets, theory reverses the order of things and presents itself as a guiding *a priori*. As Hegel (1807/1967) says, "the owl of Minerva flies only at night": the wisdom of theory arrives on the scene only after the practical events of the day (which theory captures in concepts) have been put to bed. *Theory* is a cherished way to capture an understanding of what has been learned, even if it distorts the picture by claiming that the practice out of which theory arose was a simple application of the theory's pre-existing abstract principles.

But, as the analyses of mediated cognition our seminar is studying point out, there are other *artifacts* (Cole, 1996) in which experience can be captured, preserved and transmitted. *Narrative* is one (Bruner, 1990). In this paper I have tried to project a voice which does not redefine the temporality of the experience I am reporting. *Sculpture* is another way in which people impose meaningful form on nature and,

as Hegel would say, externalize their consciousness through the mediation of wood, clay, plaster or stone – sharing it with others and preserving it as part of their culture's spirit. [1]

Polished *software* is a very different way of objectifying experience. Buried in the source code and affordances of a software artifact are countless lessons and insights – not only those of the particular software developer, but of the traditions (congealed labor) of our technological world upon which that developer built (Marx, 1867/1976). This is true of the current version of WEBGUIDE, as it is of any software application. But WEBGUIDE strives to preserve insights explicitly as well, within the notes displayed in its perspectives and within their organization, including their organization into personal and group perspectives. Perhaps when we understand better how to use WEBGUIDE in collaborative learning contexts it will maintain the knowledge that people construct through it in a way that preserves (*aufheben*) the construction process as well as the resultant theory. Eventually, collaborative practice and software design may co-evolve to the point where they can integrate the insights of multiple perspectives into group views that do not obliterate the insights of conflicting perspectives into the multifaceted nature of truth.

ISSUES FOR MEDIATION

We conclude this paper with an attempt to sort out what we are collaboratively learning through our use of WEBGUIDE. The six issues for perspectives-based software like WEBGUIDE that arose during the middle school application appeared in the graduate seminar's usage of the software as well – and were articulated by seminar participants in their notes in WEBGUIDE. These are important and complex issues that other researchers have raised as well. They are not problems that we have solved, but rather foci for future work. They define central goals for our redesign of WEBGUIDE this summer and goals for structuring the mediation of collaborative practices next year.

Here is a summary of our current understanding of these issues, based on our two practical experiences and our reflections on the theory of computer mediation of collaborative learning:

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[1] See the images of sculptures throughout this paper. Of course, my sculptures are not the result of some primordial experience of self-consciousness interacting with unmediated nature. They are late twentieth century explorations of form and material. Here, organic three-dimensional forms are showcased to contrast with socially prevalent two-dimensional representations and with the geometric shapes produced by machinery. The characteristics of the materials of nature are brought forth, in contrast to the plastic substances that retreat from our consciousness in commodities. Also, the pragmatic representational function of symbolic objects is sublimated in the study of their abstracted physical forms and materiality. In negating the commonplace characteristics of signs – which point away from themselves – the non-representational sculptures obtrusively confront their creator and viewers with the nature of the artifact as intentionally formed material object.

1. *Divergence among ideas.*

In his review of computer mediated collaborative learning, dePaula (1998) identified divergence of ideas to be a common problem. He argued that the tree structure imposed by standard threaded discussion support was inappropriate for collaboration. The idea of a threaded discussion is that one contribution or note leads to another, so that each new idea is connected to its "parent" in order to preserve this connection. The problem is that there is often no effective way to bring several ideas together in a summary or synthesis because that would require a particular note to be tied to several parent notes – something that is typically not supported by discussion software. The result is that discussions proceed along ever diverging lines as they branch out, and there is no systematic way to promote convergence. It seems clear, however, that collaboration requires both divergence (e.g., during brainstorming) and convergence (e.g., during negotiation and consensus).

WEBGUIDE tries to avoid this common structural problem of threaded discussion media at three levels: (1)The note linking mechanism in WEBGUIDE allows notes to be *linked* to multiple parents, so that they can act to bring together and summarize otherwise divergent ideas. As in threaded discussions, every note is situated in the workspace by being identified and displayed as the child of some other note. However, WEBGUIDE allows multiple parents, so that the web of notes is not restricted to a tree. (2) Similarly, the graph of perspectives allows for *multiple inheritance*, so that "comparison" perspectives can be defined that aggregate or converge the contents of multiple perspectives. The Logan School application was seeded with comparison perspectives corresponding to the class and subgroup perspectives, so that the overall perspectives graph has a structure in which the inheritance of notes first diverges from the class to the subgroup and then the personal perspectives, and then converges through the subgroup comparison perspectives to the class comparison perspective, as shown in Figure 2. The web of perspectives forms a directed acyclical graph rather than a strict hierarchy. (3) Another effective way to encourage a well-structured discussion is to seed the workspace with a set of headings to scaffold the discourse. By introducing carefully conceived *headings* high in the perspective inheritance network, a facilitator (such as a teacher) can define an arrangement of topics that will be shared by the participants and will encourage them to arrange related ideas close to each other.

Although WEBGUIDE provided these three convergence mechanisms in both of our usage situations, most participants were not adept at using any of them. This is probably related to the other issues below and is something that needs to be explored further in the future.

2. *Avoidance of system use.*

Media competition poses a barrier to acceptance of new communication software. People are naturally hesitant to adopt yet another communication technology. In a world inundated with pagers, cell phones, voicemail, email, fax, etc. people are forced to limit their media or be overwhelmed. They must calculate how much a burden the new medium will impose in terms of learning how to use it, acquiring the equipment, checking regularly for incoming messages and letting people know that they are communicating through it. Clearly, a *critical mass* of adoption by ones communication partners is necessary as well.

In a classroom context, some of these problems are minimized: all ones partners are required to use WEBGUIDE and the hardware is made available. Yet, it is not so simple. The Logan School students have to communicate with mentors who may not have Internet access or the proper hardware. Communication with classmates is much easier face-to-face then typing everything (knowing it has to be carefully

done for grading). In the graduate seminar, most participants do not have convenient access to the necessary equipment and have to go out of their way to a special lab. This means that they are lucky to communicate through WEBGUIDE once a week, and therefore cannot enter into lively on-going interchanges.

This summer we will have to make WEBGUIDE more accessible by increasing the number of platforms/browsers that it can run on and making it work over slow modems from home. Further, we need to improve its look-and-feel to increase people's comfort level in wanting to use it: speed up response time, allow drag-and-drop rearrangement of notes, permit resizing of the applet and fonts for different monitors and different eyes, support searching and selective printouts, provide graphical maps of the webs of perspectives and nodes.

3. *Naturalness of the perspectives metaphor.*

Despite the fact that WEBGUIDE has been designed to make the perspectives metaphor seem natural and simple to navigate, people express confusion as to how to use the perspectives. What perspective should I be working in, browsing for other people's ideas or entering for discussions? The metaphor of perspectives as a set of alternative (yet linked and over-lapping) textual workspaces is a new notion when operationalized as in WEBGUIDE.

The fact that an individual note may have different edited versions and different linking structures in different perspectives, that notes may have multiple parents within the discussion threads, that new perspectives can be added dynamically and may inherit from multiple other perspectives sets WEBGUIDE apart from simple threaded discussion media. It also makes the computations for displaying notes extremely complex. This is a task that definitely requires computers. By relieving people of the equivalent of these display computations, computer support may allow people to collaborate more fluidly. This is the goal of WEBGUIDE. Although the software now hides much of the complexity, it is not yet at the point where people can operate smoothly without worrying about the perspectives all together.

4. *Representation of the web of perspectives.*

One problem that aggravates acceptance of the perspectives metaphor is that the web of inheritance of content from perspective to perspective is hard to represent visually within WEBGUIDE. The WEBGUIDE interface relies on an *outline* display. This has many advantages, allowing users to navigate to and view notes of interest in an intuitive way that is already familiar. However, an outline display assumes a strictly hierarchical tree of information. Because the web of perspectives has multiple inheritance, its structure is not visible in an outline, which always shows a perspective under just one of its parents at a time. Thus, for instance, there is no visual representation of how a comparison perspective inherits from several personal perspectives.

The same is true at the level of notes. A note that has been linked to several other notes that it may summarize is always displayed as the child of just one of those notes at a time.

Two solutions suggest themselves for future exploration. One is to provide an alternative representation such as a *graphical map* in place of the outline view. As appealing as this sounds, it may be technically difficult to do on-the-fly. A bigger problem is that graphical maps are notoriously poor at scaling up. Already in our two trial situations – in which there are on the order of twice as many perspectives as participants – it would be hard to clearly label a graphical node for every perspective within the applet's confined display area. The second alternative is to indicate additional links with some kind of *icon*

within the outline view. This would require more understanding on the part of the users in interpreting and making use of this additional symbolic information.

5. *Structuring of learning situations.*

We have argued based on previous experience that the crucial aspect of supporting collaborative learning has to do with structuring social practices (Koschmann et al., 1998). *Practice* in the sense of Bourdieu's concept of *habitus* (Bourdieu, 1972) is the set of generally tacit procedures that are culturally adopted by a community. In introducing WEBGUIDE into its two user communities, we have tried to establish certain usage practices, both by instruction and by enforcement in the software. Looking back at Figure 1, you can see that Logan students are only allowed to navigate to certain perspectives – namely their personal perspective and those group perspectives that inherit from that perspective. Seminar participants were originally given *permission* to navigate throughout the system and to make changes anywhere. That was subsequently modified (as shown in Figure 3) to restrict their abilities when not in their personal perspective. The governing principle was that everyone should be able to do anything they want within their personal perspective, but no one should be able to affect the display of information in someone else's personal perspective.

When the ability to enter notes everywhere was restricted, facilities for copying and linking notes from other computational perspectives into ones own computational perspective were introduced. This was intended to encourage people to integrate the ideas from other figurative perspectives into their own figurative perspective by making a conscious decision as to where the new note should go in their existing web of notes. However, this added a step to the process of communication. One could no longer simply select a note that one wanted to comment on and press the "add discussion" button.

In order to facilitate discussion of notes that one did not necessarily want to integrate into ones own perspective, the "add discussion" button was then made active in all comparison perspectives. This led to minor problems, in that one could then not edit discussion notes that one had contributed in these perspectives. This could be fixed at the cost of additional complexity in the rules by allowing the author of a note to edit it in comparison perspectives.

More significantly, our experiments with changing permission rules pointed out that people were using WEBGUIDE primarily as a threaded discussion medium and rarely as a knowledge construction space. Furthermore, their ability to construct shared group perspectives on discussion topics was severely hampered by the lack of support for negotiation in the system.

6. *Distinguishing the system's capabilities.*

In iterating the design of WEBGUIDE it became increasingly clear that what the system "wanted to be" was a *medium for construction of knowledge*. Yet, users were more familiar with discussion forums and tended to ignore the perspectives apparatus in favor of engaging in threaded discussion. These are very different kinds of tasks: collaborative knowledge construction generally requires a prolonged process of brainstorming alternative ideas, working out the implications of different options and negotiating conclusions; discussion can be much more spontaneous.

This suggests that more clarity is needed on the question: what is the *task*? If people are going to use WEBGUIDE for collaborative knowledge construction then they need to have a clear sense of pursuing a knowledge construction task. The Logan students have such a task in articulating positions on acid mine drainage. However, much of their knowledge construction takes place in classroom discussion. They

use WEBGUIDE largely as a repository for their ideas. The seminar has been concerned with understanding a series of readings, so its participants have been more interested in exchanging isolated questions or reactions than in formulating larger integrative positions. For the remainder of the seminar, we will be trying to develop ideas for a collaborative paper on the nature of computer collaboration. This may provide the kind of focused task needed to exercise more of WEBGUIDE's potential.

Our experience to date already suggests the complexity of trying to support collaborative learning. We should probably distinguish within the software interface functions that support discussion from those that support knowledge construction. But this should be done in such a way that spontaneously discussed ideas can later be readily integrated into longer-term knowledge construction processes. Similarly, additional functionality – most notably support for group negotiation – must be added, differentiated and integrated. New capabilities and uses of WEBGUIDE can increase its value, as long as confusions and conflicts are not introduced. For instance, providing facilities for people to maintain lists of annotated Web bookmarks, things-to-do, favorite references, up-coming deadlines, etc. within their personal perspectives might not only give them familiarity with using the system, but would also build toward that critical mass of usage necessary for meaningful adoption.

It has become a cliché that computer mediation has the potential to revolutionize communication just like the printing press did long ago. But the real lesson in this analogy is that widespread literacy involved slow changes in skills and practices to take advantage of the technological affordances. In fact, the transition from orality to literacy involved a radical change in how the world thinks and works (Ong, 1998). Although social as well as technical changes can be propagated much faster now, it is still necessary to evolve suitable mixes of practices and systems to support the move from predominantly individual construction of knowledge to a new level of *collaborative cognition*.

Our investigation of the above six issues will guide the next stage of our on-going exploration of the potentials and barriers of computer mediated collaborative learning on the Web with perspectives. Because we expect the exploration of computer mediated collaborative learning to be a termless process, we will stop this paper here without a conclusions section making final claims.

ACKNOWLEDGMENTS

The WEBGUIDE research is a collaboration of the author with Rogerio dePaula and other L^{3}D members, Ted Habermann and his group at NOAA, Dan Kowal and his middle school students, the participants in the WEBGUIDE seminar, Thomas Herrmann and his students at Dortmund, and the researchers in the ICS "Articulate Learners" project. The work reported here was supported in part by grants from NSF IRI-9711951, the McDonnell Foundation and NSF EAR-9870934.

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http://www.cs.colorado.edu/~gerry/personal/recreation/form/.
Publications authored by Stahl are available at:
http://www.cs.colorado.edu/~gerry/publications/]

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